For office use only	Team Control Number	For office use only
T1 ________________	**11711**	F1 ________________
T2 ________________		F2 ________________
T3 ________________	Problem Chosen	F3 ________________
T4 ________________	**C**	F4 ________________

Let Electric Vehicles Run

Abstract

We draw a conclusion that the widespread use of electric vehicals is feasible and practical from several perspectives including environment by using comprehensive analytical methods based on multiple factors.

First of all, we make a comparison between electric vehicles and fuel ones, listing their effects on environment and health as evaluation objects and choosing emissions of HC、CO、NO2、CO2、SO2 as indexes and establishing a comprehensive evaluation model. As a result of our model, the impacts of electric vehicles and fuel vehicles are 0.571783 and 0.881803 respectively. So we reach the conclusion that, compared to traditional fuel vehicles, electric vehicles do less harm to environment and health. Then, we select Sentra and LEAF whose specifications and brands are relatively close as our research objects. Calculating their total costs, which are $100580 and $53580 separately, within their service life.

To analyze whether the government and electric vehicles are in favor of the widespread of electric vehicles, our article adopts the AHP method. The hierarchy consists of 3 levels: government's and manufacturers' stratigies as decision goal, environment, society, economy and health as decision criteria and electric vehicles and fuel ones as decision alternatives. Environment and economy are mainly considered. In addition, a summary result from our model is that government supports and subsidises the widespread use of electric vehicles but manufacturers are inclined to fuel vehicles for they are of a lager profit

We use the world mobile fleet , average oil consumption per vehicle , car journey per annum data,and base on the relationship between electricity and other energies,to caculate the world oil savings which are 80245.88 Billion liters under the widespread use of electric vehicles in 2003.,but other forms of energy consumption is increased.To forecast the amount of fossil fuels that is going to be saved, we use linear function to fit the data of world automobile fleet from 1950 to 2003.and estimate the oil savings in 2020.

Corresponding electricity demand can be estimated according to the amount and type of electric vehicles. In order to find the maximum profit of environment, society, business and individual, we form a multi-objective optimization model whose

objective functions are energy consumption costs and emission of carbon dioxide. Reffering to Kaya idensity, we reach a quantative relations between emission of carbon dioxide and energy consumption, which embraces the consumption of coal, petroleum, natural gas, nuclear energy and some new energies. Eventually, Genetic Algorithm is adopted to solve the model and we obtained the proportion of different energy sources.

I. Introduction

Since the 1990s, the world is paying increasing attention to climate change mainly featuring global warming.The 4^{th} assessment report published by IPCC in 2007, which put further emphasis on the fact that economic activities including the use of fossil fuels have become one of the chief driving forces that lead to the greenhouse gas increase in atomosphere, which is a main cause of global warming. Today,since energy saving and emission reducing is required globally, that how to stay friendly with the environment as well as meet the demand of fuel use has been upgraded into a major project. Meanwhile, some creation emerges, for instance, electric vehicle.

There is no doubt that relative to conventional gasoline-powered vehicles (CVs), electric vehicles will provide several societal benefits. Electric vehicles can play a role in decreasing transportation-related oil consumption by using electricity as a transportation fuel. Depending on the source of the electric power, they are likely to reduce greenhouse gas (GHG) emissions and criteria air pollutants. Reducing oil consumption, criteria pollutants, and GHG emissions are all widely accepted as indicators of sustainability in the transportation sector. In addition to providing a solution to urban air-quality problems, EVs would provide an alternative to conventional vehicles (CVs),

EV technology, however, is at an early stage of development. Low production volumes and labor-intensive manufacturing processes make the costs of its components high. When EVs come to be produced in sufficient volume, significant cost reductions will be possible. The EV's electric drive components, which currently have very high costs, could be produced in large quantities at reasonable cost.

In this paper, we establish the comprehensive evaluation model and AHP model firstly to study the the corresponding factors of widespread use of electric vehicles including changes in GHG emissions, gasoline consumption, Costs and benefits,and convinience or not from societal perspective. We subsequently formulate and solve a simple analytic model to estimate how much oil the world would save by widely using electric vehicals.Finally,consider the situation of electric vehicles,we develop a multi-objective optimization model to planning the best number and type of electric generation .

II. Models

2.1 Evaluation of the impact of electric vehicl*es*

2.1.1Analysis

To make the feasibility of the popularity of electric vehicles. First ,we need to know the impacts electric vehicles have on the environment, society , economy and health. Pollution of the environment caused by electric vehicles itself is extremly low, but the electric vehicles' consumption of electricity is supplied by power plants, and power plants use coal, natural gas and other resources in power generation, which will bring some environmental pollution. That is the invisible pollution of electric vehicles. The mainly social impact of electric vehicles is the convenience on transportation, ease of charging ,etc. Electric vehicles' influence on the human health is related to the electric vehicle emissions of harmful gases and noise.

2.1.2 Symbols and Definitions

F The object of comprehensive evaluation model

x_1 The emissions of HC

x_1 The emissions of CO

x_1 The emissions of NO_2

x_1 The emissions of CO_2

x_1 The emissions of SO_x

2.1.3 Assumptions

The vehicles' pollutants just caused by the emissions of HC, CO, NO2, CO2, SO_x, ignore the relationship between various indicators.

2.1.4 Evaluation of the environmental impact of electric vehicles

In order to have better assess on impact of the widespread use of electric vehicles on environment, society, economy and health, as well as the feasibility of the popularity of electric vehicles. In this article ,we will compare electric vehicles with traditional fuel vehicles to find out their influences ,on the environment, etc.

First, the assessment of the influences electric vehicles and fuel vehicles have on the environment .Here we use Comprehensive evaluation model.

- **Evaluation of selection of objects**

Object evaluated is the influence created by electric vehicles and fuel vehicles, on the environment , etc.

- **Evaluation of the index**

Pollutants caused by the use of electric vehicles and fuel vehicles, such as HC, CO, NO2, CO2, SO_x.

- **Modeling**

As the influence caused by electric vehicles is very low, we take it as negligible. We focus on the invisible influence caused by the electric vehicles. This is because electric vehicles is based on consumption of energy, and energy consumption of other energy generation needs, which will produce air pollution, waste pollution, noise pollution. As we can see the following data collected from the U.S. General Motors electric vehicle technology reports :

Table 1

The emissions of energy

	Emissions（kg）	
Pollutant	Fuel vehicles	Electric vehicles
HC	0.018	0.004236
CO	0.91	0.007644
NO_2	0.0771	0.174156
CO_2	83	51.06
SO_x	0.22095	0.228654

As shown, on one hand, lead-free petrol emissions of traditional vehicles ,such as HC, CO, NO_2, CO_2, SO_x, respectively 0.018,0.910,0.0771,83,0.22095 kg. On the other hand, Electric Vehicle exhaust emissions including power plants gas emissions shows in the table , data for integrated coal, natural gas, wind energy, solar power generation by the gas emissions. After comparison, its meaning is the same with traditional fuel vehicles.

Take the effects caused by internal combustion vehicles and electric vehicles as evaluation objects, the emissions of HC, CO, NO_2, CO_2, SO_x as evaluation index to establish comprehensive evaluation model:

$$F = w_1 x_1 + w_2 x_2 + ... + w_j x_j ,\ j = 1, 2, \cdots, 5.$$

Among them, $x_1, x_2 ... x_j$ as evaluation index, $w_1, w_2 ... w_j$ as corresponding weight.

- **Model Solution**

(1) First, take the evaluation indicators to the non-dimensional processing.

For the magnitude of data in the table is inconsistent, so we should take the various indicators to non-dimensional processing.

(2) Weight selection. Assign evaluation of a weight to the same, taken as 0.2.

(3) Calculation of variable

From the formula : $F = w_1 x_1 + w_2 x_2 + ... + w_j x_j$,variable of the effects electric vehicles and fuel vehicles have on the air are 0.571783, 0.881803 respectively.

2.1.5 The assessment of the health effects of electric vehicles.

Because electric vehicles HC, CO, NO2, SO2 emissions are closely related to human health. Take the effects internal combustion vehicles and electric vehicles have on health as evaluation object, HC, CO, NO2, SO2 emissions as evaluation indicators, to establish a comprehensive evaluation model.
By using the same method ,we can get the variables of the effects electric vehicles and internal combustion vehicles have on the health are 0.448747,0.681803 respectively.

2.1.6The assessment of the social impact of electric vehicles.

Assess the social convenience of electric vehicles. Fast charging for electric vehicle normally costs 30 minutes, slow charging costs 4 to 8 hours or so. But the fuel vehicle’s refueling generally cost no more than 10 minutes. In addition the current charge is generally applied to short-distance transport, fuel vehicles are used in short and long-distance transport. Electric vehicles stroke each charge storage time for 100 to 200 kilometers,while the largest fuel vehicles travel 300 km in the same condition. From a social point of view, internal combustion vehicles bring more convenience than electric vehicles.

2.1.7The assessment of the economical impact of electric vehicles

The economic impact of electric vehicles. In this article ,we consider its economic impact from the vehicle's full life-cycle costs .To facilitate the discussion, we take the Nissan Sentra and Nissan Master the wind LEAF electric cars for example to compare the different cost by different vehicles types, reaching the following data:

Table2

The cost of Nissan Sentra and Nissan Master

COMPARED OBJECTS	LEAF	SENTRA
Sale Price（1）/Yuan	32，780	15,930
Energy Rate（2）/100km	1.56	6.63
Full life mileage/100km	5,000	5,000
While life operating costs（4）=（2）×（3）	7，800	33，150
Mintenance costs （5）/Yuan/year	1500	450
Entire vehicle life（6）/年	10	10
Total maintenance costs（7）=（5）×（6）	15000	4500
Battery life（8）/100km	400	0

Battery pack price (9) /Yuan/Group	3000	0
The number of battery (10) replacement/times	15	0
Battery cost (11) = (9) × (10) /Yuan	45000	0
Life cycle cost (12) = (1) + (4) + (7) + (11) /Yuan	100580	53580

From the table, we can reach the result that the full-cycle costs of this electric vehicle and fuel are $ 100,580, $ 53,580 .
Life-cycle costs of electric vehicles is nearly twice the fuel vehicles. Since there is no fuel consumption to run LEAF , the energy cost is only 23.5% of Sentra.However, battery cost and sale price is 77.33% of life cycle cost . These two seriously affected the economy of electric vehicles.So , vehicle manufacturers should reduce the costs of car and battery production.
To sum up, from an economic point of view, it’s better to chose fuel vehicles.

2.1.8 Sensitivity

We select electricity price, oil price, battery life, battery price and sale price to do life cycle cost sensitivity analysis.Set parameters varies from -10% to 10%,calculate the sensitivity coefficients $\beta = \Delta A / \Delta F$ of each parameter. ΔA is parameter occur (20%) rate of change,the corresponding change rate of index A (%).As shown in the table.:

Sentra

parameter	parameter change rate					β
	−10%	−5%	0	5%	10%	
oil price	−6. 19%	−3. 09%	0	3. 09%	6. 19%	61. 87%
electricity price	−	−	−	−	−	−
battery price	−	−	−	−	−	−
battery life	−	−	−	−	−	−
sale price	−2. 97%	−1. 49%	0	1. 49%	2. 97%	29. 73%

LEAF

parameter	parameter change rate	β

	−10%	−5%	0	5%	10%	
oil price	-	-	-	-	-	-
electricity price	-0.78%	-0.39%	0	0.39%	0.78%	7.76%
battery price	-4.47%	-2.24%	0	2.24%	4.47%	44.71%
battery life	4.97%	2.35%	0	-2.13%	-4.07%	-45.19%
sale price	-3.26%	-1.63%	0	1.63%	3.26%	32.59%

Through horizontal comparison shows that the size of the sensitivity factors are Factors affect the sensitivity of electric LEAF the order is sale price,battery price,battery life,electricity price.While for Sentra ,they are oil price and sale price.

2.2 *Analytical hierarchy process model*

2.2.1The AHP methodology

The AHP is a method developed by Saaty (1980) to support multi-criteria decision making. It involves decomposing a complex MCDM problem into a hierarchy, assessing the relative importance of decision criteria, comparing decision alternatives with respect to each criterion, and determining an overall priority for each decision alternative and an overall ranking for the decision alternatives. The hierarchy is constructed in such a way that the overall decision goal is at the top level, decision criteria (and sub-criteria if any) are in the middle level(s), and decision alternatives at the bottom, in our model, the overall decision goal is the selection of vehicles' type, decision criteria are environment、society、economy and health, decision alternatives are electric vehicles and fuel vehicles,as shown in Fig. 1.

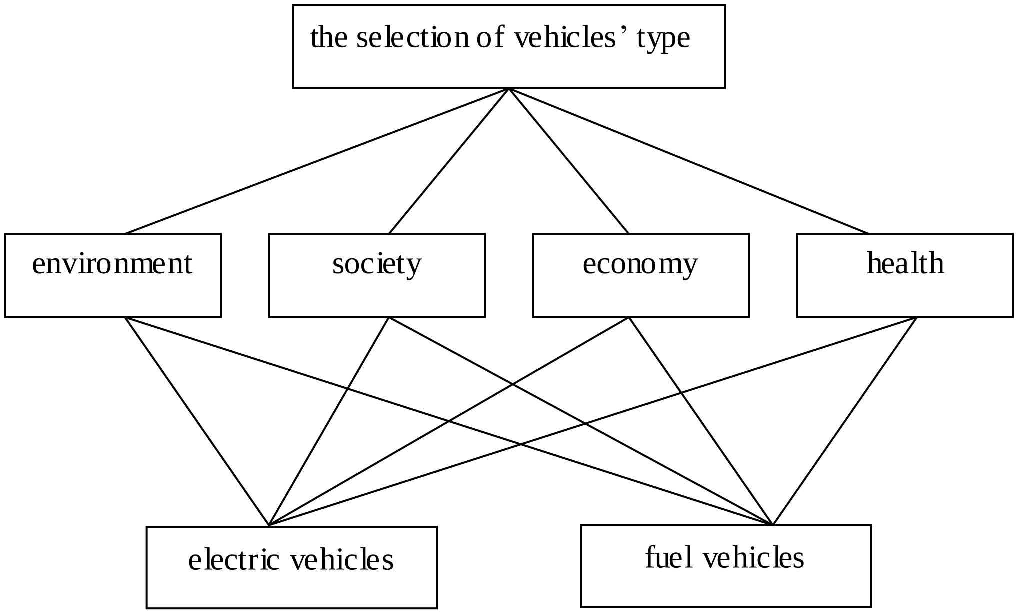

Fig. 1. Hierarchy for a typical three-level MCDM problem.

The AHP method provides a structured framework for setting priorities on each level of the hierarchy using pairwise comparisons that are quantified using 1–9 scales in Table 3

Table 3

The 1–9 scales for pairwise comparisons in the AHP

Importance intensity	Definnition
1	Equal importance
3	Moderate importance of one over another
5	Strong importance of one over another
7	Very strong importance of one over another
9	Extreme importance of one over another
2，4，6，8	Intermediate values
Reciprocals	Reciprocals for inverse comparison

. Let $C_1,...,C_m$ be m decision criteria and $W=(w_1,...,w_m)^T$ be their normalized relative importance weight vector, which is to be determined by using pairwise comparisons and satisfies the normalization condition $\sum_{j=1}^{m} w_j = 1$ with $w_j \geq 0$ for $j=1,...,m$ The pairwise comparisons between the m decision criteria can be conducted by asking the decision maker (DM) or expert questions such as which criterion is more important with regards to the decision goal and by what scale (1–9).

The answers to these questions form an $m \times m$ pairwise comparison matrix which is defined as follows:

$$A=(a_{ij})=\begin{array}{c} C_1 \\ C_2 \\ \vdots \\ C_M \end{array}\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \vdots & \vdots & \cdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{3m} \end{bmatrix}$$

where a_{ij} represents a quantified judgment on w_i / w_j with $a_{ij}=1$ and $a_{ij}=1/a_{ji}$ for $i, j=1,...,m.$.f the pairwise comparison matrix $A=(a_{ij})_{m\times m}$ satisfies $a_{ij}=a_{ik}a_{kj}$ for any $i, j, k=1,...,m$, then A is said to be perfectly consistent;otherwise it is said to be inconsistent. Form the pairwise comparison matrix A, the weight vector W can be determined by solving the following characteristic equation:

Form the pairwise comparison matrix A, the weight vector W can be determined by solving the following characteristic equation:

$$AW=\lambda_{\max}W$$

where $\lambda_{\max}$ is the maximum eigenvalue of A. Such a method for determining the weight vector of a pairwisecomparison matrix is referred to as the principal right eigenvector method (EM) (Saaty, 1980).

Since the DM may be unable to provide perfectly consistent pairwise comparisons, it is demanded that the pairwise comparison matrix A should have an acceptable consistency, which can be checked by the following consistency ratio (CR):

$$CR=\frac{(\lambda_{\max}-n)(n-1)}{RI}$$

where RI is a random inconsistency index, whose value varies with the order of pairwise comparison matrix**.**Table 4 shows the RI values for the pairwise comparison matrices with the order from 1 to 10.

Table 4

Random inconsistency index for pairwise comparison matrices with the order from 1 to 10

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

If $CR \le 0.1$, the pairwise comparison matrix is thought to have an acceptable consistency; otherwise, it need to be revised.Decision alternatives can be compared pairwisely with respect to each decision criterion in the same way. After the weights of decision criteria and the weights of decision alternatives with respect to each criterion areobtained by using pairwise comparison matrices, the overall weight (or called priority) of each decision alternative with respect to the decision goal can be generated by using the following simple additive weighting (SAW) method **(Hwang & Yoon, 1981)**:

$$w_{Ai} = \sum_{j=1}^{m} w_{ij} w_j, i = 1, ..., n.$$

where $w_j (j = 1, ..., m)$ are the weights of decision criteria, $w_{ij} (i = 1, ...n)$ are the weights of decision alternatives with respect to Criterion j, and $w_{Ai} (i = 1, ...n)$ are the overall weights of decision alternatives. Table 5 shows how the overall weights can be computed on a table easily and conveniently. Based upon the overall weights of decision alternatives, decision can be made and the alternatives can be ranked or prioritized.The best decision alternative will be the one with the biggest overall weight with respect to the decision goal.

Table 5

Computation of overall weights

Alternative	Decision criteria					Overall weight
	C_1	$\cdots$	C_j	$\cdots$	C_m	
	w_1	$\cdots$	w_j	$\cdots$	w_m	
A_1	w_{11}	$\cdots$	w_{1j}	$\cdots$	w_{1m}	$w_{A1} = \sum_{i=1}^{m} w_{1j} w_j$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
A_i	w_{i1}	$\cdots$	w_{ij}	$\cdots$	w_{im}	$w_{Ai} = \sum_{j=1}^{m} w_{ij} w_j$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
A_n	w_{n1}	$\cdots$	w_{nj}	$\cdots$	w_{nm}	$w_{An} = \sum_{j=1}^{m} w_{nj} w_j$

2.2.2Solution and Result

Step1 The weights of criteria should be determined by the government or vehicle manufactures. If environment is the first factor that government consider when making choice,so we can suppose the pairwise comparison matrix for the four assessment criteria is as follows:

$$A = \begin{pmatrix} 1 & 2 & 2 & 3 \\ 1/2 & 1 & 1 & 2 \\ 1/2 & 1 & 1 & 2 \\ 1/3 & 1/2 & 1/2 & 1 \end{pmatrix}$$

whose maximum eigenvalue is $\lambda_{\max} = 4.0104$ and the corresponding normalized principal right eigenvector is $W = (0.4236, 0, 2270, 0.2270, 0.1223)$.

The consistency index for the above paired comparison matrix is:

$$CR = \frac{(\lambda_{\max} - n)(n-1)}{RI} = 0.004 \le 0.1$$

So the above pairwise comparison matrix is thought to have acceptable consistency and its normalized principal right eigenvector can be used as the weights of criteria.

Step2 Calculate the weights of decision alternatives with respect to the Criterion

For the reason that the environmental impact of electric vehicles' and fuel vehicles' are 0.571783 and 0.881803 respectively,so the pairwise comparison matrix between decision alternatives and environment is as follow:

$$\begin{pmatrix} 1 & 2 \\ 1/2 & 1 \end{pmatrix}$$

Similarly, the pairwise comparison matrix between decision alternatives and the other decision criteria are as follow:

$$\begin{pmatrix} 1 & 1/2 \\ 2 & 1 \end{pmatrix}、\begin{pmatrix} 1 & 1/2 \\ 2 & 1 \end{pmatrix}、\begin{pmatrix} 1 & 2 \\ 1/2 & 1 \end{pmatrix}.$$

In accordance with the pairwise comparison matrix above,we figure out the overall weights of electric vehicles and fuel vehicles are 0.5153、0.4498.

on the other hand, If economic is the first factor that vehicle manufactures consider when making choice,we can suppose the pairwise comparison matrix for the four assessment criteria is as follows:

$$A = \begin{pmatrix} 1 & 2 & 1/3 & 2 \\ 2 & 1 & 1/2 & 3 \\ 3 & 2 & 1 & 3 \\ 1/2 & 1/3 & 1/3 & 1 \end{pmatrix}$$

Similarly,we get the data that the overall weights of electric vehicles and fuel vehicles are 0.4421、0.4517.

It can be seen from the results that, the pollution and health hazard caused by electric vehicles is little,so the government shoud take measures to support the development and use of electric vehicles.Because of the high cost of electric vehicles,the government should provide allowance for electric vehicles consumer. The manufacturer , however,do not support the development and use of electric vehicles.

2.3 Electric vehicle alternative fuel vehicles Energy Savings Analysis

Global oil consumption per year is tightly linked with global total vehicle amount, average oil consumption per vehicle and car journey per annum.In order to estimate how much oil (fossil fuels) the world can save by widely using electric vehicles, we use historical data of world automobile fleet from *Ward's Communications, Ward's World Motor Vehicle Data* (Southfield, MI: 2010) in the table below:

Table 6

world automobile fleet

Year	Number	Year	Number	Year	Number	Year	Number
1950	53	1964	130	1978	297	1992	470
1951	56	1965	140	1979	308	1993	470
1952	58	1966	148	1980	320	1994	480
1953	62	1967	158	1981	331	1995	477
1954	67	1968	170	1982	340	1996	464
1955	73	1969	181	1983	352	1997	478
1956	78	1970	193	1984	365	1998	489
1957	83	1971	207	1985	374	1999	496
1958	86	1972	220	1986	386	2000	509
1959	92	1973	236	1987	394	2001	520
1960	98	1974	249	1988	413	2002	530
1961	105	1975	260	1989	424	2003	539
1962	113	1976	269	1990	445		
1963	121	1977	285	1991	456		

According to the table, it could be seen that world automobile fleet reached 539 million, moreover, it kept a persistent increase from 1950 to 2003.If we do not choose renewable vehicles, the total oil consumption per year will be considerable. Therefore, promoting electric vehicles boasts remarkable advantages in protecting environment and saving energy.

Data from the table is summed up from .It's assumed that the average car journey per car each day is 450 km, namely 150000 km per car per year, therefore, the average oil consumption per vehicle is 0.1 l/km.We use TOC to represent total oil consumption and use WAF,TTY,OCK to represent world automobile fleet, Total travel per vehicle year, Oil consumption per kilometer ,respectively.So that:

$$TOC = WAF \times TTY \times OCK$$

It can be calculated that global oil consumption of vehicle is 8.085 trillion litres.Supposing that these vehicles are turned into electric ones, 8.085 trillion litres are saved. However, electric vehicles require electricity and the electricity is currently mostly produced by burning fossil fuels. To analyse whether the wide spread use of electric vehicles actually save fossil fuels not merely trading one use of fossil fuels for another, we should take energy transformation between electricity and fossil fuels into account.

On the assumption that electric vehicle uses 34kWh per 100 miles (about 161 kilometres), we can conclude that all these electric vehicles consume a total of 17.073913 trillion kWh. Energy transformation between electricity and other energies can be summed up as follows based on statistics from http://www.eia.doe.gov/aer/pecss diagram.html .

Table 7

The proportion of energy generating capacity

Energy species	Coal	Petroleum	Natual gas	Nuclear	Renewable energy
Proportion	48%	1%	18%	22%	11%

On the basis of coal corprations'energy sheet, power plants consume 404gram standard coal averagely to generate 1kWh.Other energies' discount factors of standard coal are below:

Table 8

Energies' discount factors of standard coal

Energy species	Average low power	Discount factor of standard coal
coal	20908KJ/（5000Kcal）/Kg	0.713
oil	41816KJ/（10000Kcal）/Kg	1.4286
natual_gas	38931KJ/（9310Kcal）/m	1.33
electricity	11838KJ/（2828Kcal）/KWh	0.404

(In the charter above, units of natural gas and electricity are cubic meters and kWh respectively)

To work out the amount of fossil fuels saved by replacing normal vehicles, first of all, we use the formula(TER represents Total electricity consumption and ECK represents electricity consumption per kilometer):

$$TEC = WAF \times TTY \times ECK$$

After get the total electric vehicles'electricity consumption,we use UPO,TCE,POG to Unit power consumption of oil , Total annual consumption of electric vehicles, The proportion of oil generation. so that:

$$TOC = UPO \times TCG \times POG$$

Same, we use the formulas to calculate the amount of petroleum, natural gas and coal that consumes.The results are 48.3297billion kilogram, 933.2501billion cubic meters and 4.642254billion kilograms separately.

As the results show, supposing that electric vehicles were widely used in 2003, the oil consumption can be decreased by 80245.88 litres. On the other hand, the coal consumption and natural gas consumption would go up. However, if we raise the proportion of wind power generation and solar generation, the fossil fuels can be cut down greatly.

To forecast the amount of fossil fuels that is going to be saved, we use linear function to fit the data of world automobile fleet from 1950 to 2003. Results are as follows:

Table 9

The results of fitted value

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.0369	4.8637	-0.0075	0.994
T	1.1846	0.1538	66.1913	0
R-squared=0.9883, Adjusted R-squared=0.9881				
F-statistic=4381.292, Prob(F-statistic)<0.001				

We can see that, R-squared=0.9883. This illustrates it fits well wholly. The fitting graph is below:

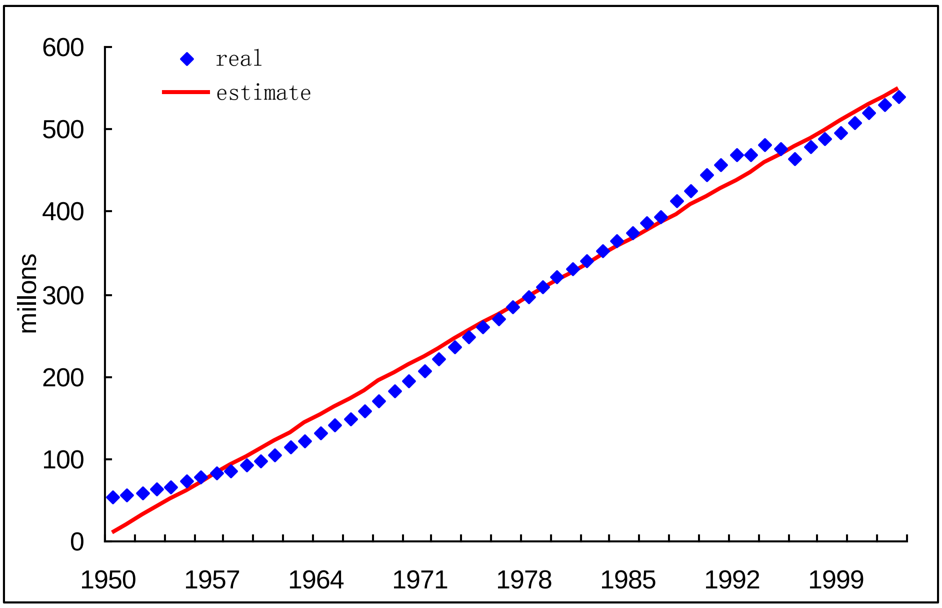

Fig 2: The fitting graph

The future world automobile fleet can be estimated by using the equation: $y = -0.0369 + 1.1846t$ .Results are as follows:

Table 10

The results of prediction

2005	2010	2015	2020
570.302	621.2252	672.1483	723.0714

The results from the table, we can see that the total number of cars around the world will reach the amount of 723.0714 million in 2020.. Shown by the http://car.southcn.com/7/2010-06/12/content_12815296.htm, penetration of electric vehicles worldwide by 2020 will not exceed 15%, so we assume that electric vehicles in 2020 will reach the maximum penetration rate of 15%,.Obtained by the previous formula ,the use of electric vehicles in 2020 will save the oil of 1505.345 l.,but need to consume the amount of natural gas, and coal were 1877.94 Billion cubic meters and

9341.412 Billion kg.

2. 4 Multi-objective optimization model

2.4.1Introduction

Since the 1990s, the world is paying increasing attention to climate change mainly featuring global warming.The 4th assessment report published by IPCC in 2007, which put further emphasis on the fact that economic activities including the use of fossil fuels **(and the change of land use)** have become one of the chief driving forces that lead to the greenhouse gas increase in atomosphere, which is a main cause of global warming.

It can be seen that the use of fuel is closely related to the emission of carbon dioxide. Today,since energy saving and emission reducing is required globally, that how to stay friendly with the environment as well as meet the demand of fuel use has been upgraded into a major project. Meanwhile, some creation emerges, for instance, electric vehicle. Due to the variation in the unit emission of fuels, this chapter designs a carbon dioxide emissions control model with regression analysis.

2.4.2 Symbols and Definitions

Y The emissions of Carbon dioxide

Y_1 The proportion of coal power generation

Y_2 The proportion of petroleum power generation

Y_3 The proportion of natural gas power generation

Y_4 The proportion of coal nuclear generation

Y_5 The proportion of Renewable energy power generation

2.4.3 Assumptions

All the data sources are accurate and reliable.

We just consider the pollution of CO_2 .

2.4.4 The control model of carbon dioxide emissions

When developing our model, we refer to Kaya idensity which is introduced by professor Kaya in a IPCC session in 1989 for the first time. Kaya idensity combines factors, such as economy, politics, popultion etc, with the amount of carbon dioxide produced by human activities. It can be illustrated below:

$$CO_2 = \frac{CO_2}{PE} \times \frac{PE}{GDP} \times \frac{GDP}{POP} \times POP$$

Here, C02、PE、GDP and POP represents carbon dioxide emissions, the primary energy consumption, gross domestic product and domestic population respectively. C02 / PE、PE / GDP and GDP / POP can also be called the energy structure of the carbon intensity, unit GDP energy intensity and per capita GDP therein.

When we referring to Kaya idensity to formulate a regression model concering economy, energy and environment, American coal generating capacity is taken into consideration firstly.

$$X_1 = \ln(COAL / PE) \qquad X_2 = \ln(PE / GDP)$$

$$X_3 = \ln(GDP / POP) \qquad X_4 = \ln(POP) \qquad Y = \ln(CO_2)$$

Our model is established as follows:

$$Y = Const + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

Now we provide the regression results below. (The results were obtained from the statistical package Eviews 5.0)

$$Y = -12.7433 + 0.0366 X_1 + 1.1814 X_2 + 1.0193 X_3 + 1.7047 X_4$$

Regression test results are as follows:

Table 11

The results of fitted value

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-12.7433	6.63542	-1.9205	0.087
X1	0.36631	0.118362	3.094815	0.0128
X2	1.181428	0.147316	8.019659	0
X3	1.019309	0.13144	7.754929	0
X4	1.704686	0.535534	3.183152	0.0111
R-squared=0.981204, Adjusted R-squared=0.97285				
F-statistic=117.4535, Prob(F-statistic)<0.001				

From the result,we can see :the observed R-squared is 0.981204 which suggests the sample regression line fits the data very well. The p value of obtaining an F value of as much as 117.4535 or greater is almost zero,leading to the rejection of the hypothesis that together X_1, X_2, X_3, X_4 have no effect on Y.Applying the t test, we obtain p value of t test of X_1, X_2, X_3, X_4 are all less than 0.05,so we say reject H_0,and statistically significant.Therefore, we accept the model.

Next,by substituting $X_1 = \ln(COAL / PE)$，$X_2 = \ln(PE / GDP)$，$X_3 = \ln(GDP / POP)$，

$X_4 = \ln(POP)$， $Y = \ln(CO_2)$ into the equation of the regression aboveand use the data of PE,GDP and POP in 2009,we get the relationship between U.S. coal power generation and Carbon dioxide emissions,so:

$$\ln(CO_2) = -5.8595 + 0.3663\ln(Y_1)$$

In the same way,we get the relationship between other energy power generation and Carbon dioxide emissions as below:

$$\ln(CO_2) = 0.1422 + 0.0201\ln(Y_2)$$

$$\ln(CO_2) = -7.1023 + 0.0026\ln(Y_3)$$

$$\ln(CO_2) = -6.9364 + 0.0042\ln(Y_4)$$

$$\ln(CO_2) = -0.2567 - 0.0534\ln(Y_5)$$

From these equations， we get the control model of carbon dioxide emissions：

$$\ln(CO_2) = -4.0026 + 0.3663\ln(Y_1) + 0.0201\ln(Y_2) + 0.0026\ln(Y_3) + 0.0042\ln(Y_4)$$

$$-0.0534\ln(Y_5)$$

2.4.4 The Foundation of Multi-objective optimization model

To analysis the amount and type of electricity generation ,we take U.S as research subject.

Firstly, we calculated the total energy required corresponding to he amount and type of electric vehicle use . In the U.S 27% of total energy is consumed by transportation sector .(http://www.eia.gov)

Then,we research the energy structure optimization for generating electric power. Obviously, this is a multi-objective optimization problem.

First,selection of Objective Function

In this paper, we research the main aspects of the problem.:environmental and business benefits.In turn, they will affect the benefits of society and individuals seriously.

(1)total energy consumption

Total energy consumption is the most obvious manifestation related to the economic aspects ,The most important aspect is the minimum value of energy consumption in the pursuit ofoptimal energy efficiency.Therefore, the minimum value for energy consumption is one of the most important goals

Objective function expression as follows：

$$\min\ f_1 = \sum_{i=1}^{5} C_i Y_i$$

(2)Carbon Dioxide Emissions

Developed by the International Covenant on carbon dioxide emissions limit is triggered one of the reasons for this goal.Therefore, it is a main goal to emission the least carbon dioxide without affecting domestic economic development and energy use .

Assume f_2 is carbon dioxide emissions，according to The Control Model of Carbon Dioxide，the objective function formula is as follows：

$$\ln f_2 = -4.0026 + 0.3663\ln(Y_1) + 0.0201\ln(Y_2) + 0.0026\ln(Y_3) + 0.0042\ln(Y_4)$$

$$-0.0534\ln(Y_5)$$

Second,the selection of constraints

Limits of carbon dioxide emissions

According to the Federal Environmental Protection Law，the total carbon dioxide emissions from all kinds of electricity generation shall not exceed the state limit carbon dioxide emissions.According to The United Nations Intergovernmental Panel on Climate Change (IPCC),United States indicated that in 2005, carbon dioxide emissions will be reduced 17% on the basis of of2020.Because the model Study the 2009 data ，So we assume that carbon dioxide emissions in 2009 can not exceed the amount of carbon dioxide emissions in 2005

(a) The resulting constraints；

$$f_2 \le U$$

where，U is the upper limit of total carbon dioxide emissions:5973.31018074448。

(b)Limits of energy supply and demand balance

Sources of electricity are coal, oil, natural gas, renewable energy,and nuclear energy .

And energy consumption shall not exceed the upper limit of energy supply

That is

$$Y_i \le b_i$$

Where b_i is the i Species of total domestic energy supply ceiling.

As the uncertainty of forecasts, some of the objectives and constraints may be overestimated or underestimated.

The multi-objective optimization model：

$goals$:

$\min f_1$

$\min f_2$

s.t

$$\begin{cases} f_1 = \sum_{i=1}^{5} C_i Y_i \\ \ln f_2 = -4.0026 + 0.3663\ln(Y_1) + 0.0201\ln(Y_2) + 0.0026\ln(Y_3) \\ +0.0042\ln(Y_4) - 0.0534\ln(Y_5) \\ f_2 \le U \\ 0 \le Y_i \le b_i \end{cases}$$

Because it is extremely difficult to solve multi- programming，we transform the model above into single-objective model:

$$\min F = \omega_1 f_1 + \omega_2 f_2$$

$$\begin{cases} f_1 = \sum_{i=1}^{5} C_i Y_i \\ \ln f_2 = -4.0026 + 0.3663\ln(Y_1) + 0.0201\ln(Y_2) + 0.0026\ln(Y_3) \\ +0.0042\ln(Y_4) - 0.0534\ln(Y_5) \\ f_2 \le U \\ 0 \le Y_i \le b_i \end{cases}$$

where ω_1 、 ω_2 are the corresponding weights.They are desirable for policymakers to choose different values.

As the objective function in this model is nonliner,it is hard to get optional solution with traditional methords.Based on it's simplicity, ease of operation, minimal requirements and parallel and global perspective, genetic algorithm has been widely applied in sloving optimization problems.Because this is a multiobjective optimization and nonliner probrom, we chose GA to solve it.

Basic theory and algorithm process of multiobjective genetic algorithm.

Nowadays，there are there strategies to solve multi-objective optimization problem by using genetic algorithms :

①Standard quantitative methods：usually multiple objectives into a single objective to optimize，linear weighting method and minimax method included;

②NonPareto based on population：The objective function in turn affect different species in the choice of different individuals，different according to each objective function .

③method based on Pareto： individuals in population sort based on Pareto.

(a)Linear weighting method

For the functions $f_1(x), f_2(x), \cdots, f_n(x)$, $\omega_1, \omega_2, \cdots, \omega_n$ are the corresponding weights.Find optimal solution for fitness function

$$F(x)=\sum_{i=1}^{n}\omega_i f_i(x)\text{.}$$

(b)Minimax method

Seek the most advantageous solution strategy in the most adverse conditions.

This methord help seek the most advantageous solution strategy in the most adverse conditionsm.Firstly,seek the optional solution of every objective function. And then seek the minimum of these maximum values,that is $F(x)=\max f_i(x), 1\le i\le n$。 The original multi-objective problem is transformed into minimization problem solving.

This transformation is a single objective programming， which is suitable for the first method .

Considering it is hard to seek optional directly， we transform multiple s into a single objective,and take linear weighting method.

Algorithm process

Genetic algorithms(GA) is a class of population-based search algorithm,

This feature allows a genetic become algorithm the most natural choice. to solve multi-objective optimization problem (MOP) . Run once, it may find a few Pareto optimal solutions.

The genetic algorithm applied to multi-objective optimization problem is different from the single-objective genetic algorithm.

Two key issues in Multi-objective genetic algorithm implementation process：

①How to define the fitness fuction; ②How to maintain the diversity.Considering the purpose to produce the lagest number of benefits ,our model chose the objective function as fitness function.To maintain the diversity,we develop a new methord.

Algorithm: The overall algorithm for the electricity generation optimization is as follows:

Step 1: Set the parameters, population size (popsize), population percentage mutated (p_{m1}), mutation rate (p_{m2}), the maximum generation (maxgen) and initialize number of generations gen = 0.

Step 2: Initialize

a) Randomly generate the initial population

b) Send the initial population for reliability calculation

c) Send the initial population to the cost calculation function (fitness).

If infeasible chromosome exist, they are penalized.

d) Test for the best initial solution. If no chromosome is feasible, the best infeasible chromosome is recorded.

Step 3: Selection

a) Insert the best chromosome into the new population

b) Select two distinct candidate chromosomes from the current population by the rank-based selection process.

Step 4: Perform Crossover. Uniform crossover is performed.

Step 5: Perform Mutation. After crossover once a child is created, then mutate it.

Step 6: Check the number of children. If n <popsize-1, goto step 3; else goto step 6, where n represents the number of new children.

Step 7: Form the new population. Replace the parents with children that are created.

Step 8: Evaluate

a) Send the new population to the reliability calculation function

b) Calculate fitness function for each chromosome in the new population. If infeasible chromosome exist, they are penalized

Step 9: Check for the best new chromosome. Save the best new chromosome;if no chromosome is feasible, then the best infeasible chromosome is noted.

Step 10: Check the terminating condition. If gen<maxgen, gen=gen+1, and goto step 3 for the next generation. If gen = maxgen, then terminate.

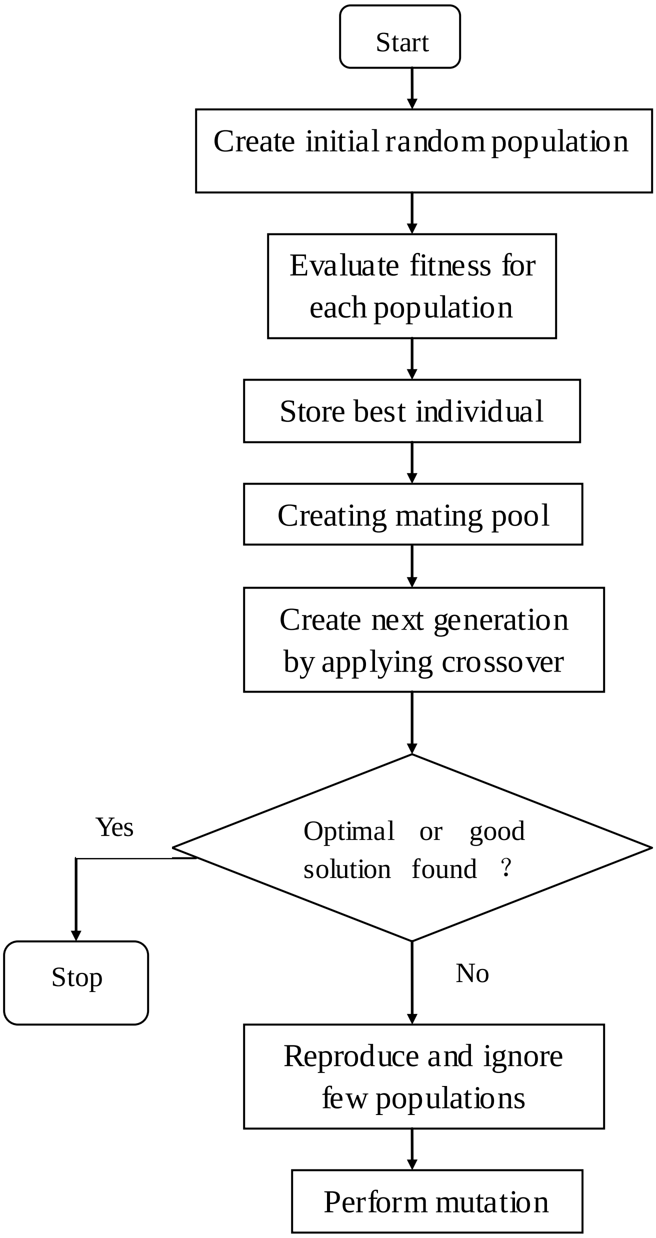

Fig3: Flowchart of genetic algorithm

The algorithm above is a general framework of genetic algorithm, it can be improved on this basis:

GA's effciency and accuracy depends on the initial population.To get a better the initial population,we divide the interval of each parameter value to N equal portions.So that all parameter values at each interval

This approach can make the initial population uniformly distributed in the interval of each parameter value.Reduces the possiblity to produce local optimal solution .Assuming the value of each individual interval

To deal with large amounts of data,we designed a three-dimensional array to store data.For a M-by-N-by-P,M is arameter’s type number，N corresponds to a list of date cover the entire parameter range,P corresponds to population number.

Thus the multi-objective optimization problem can be efficiently solved using Genetic algorithm approach.
According to algorithm,we program with MATLAB7.0.1, take two different weights [0.8,0.2], [0.2,0.8],obtain the corresponding ratio .In order to describe the problem more image, We draw pie chart as below:

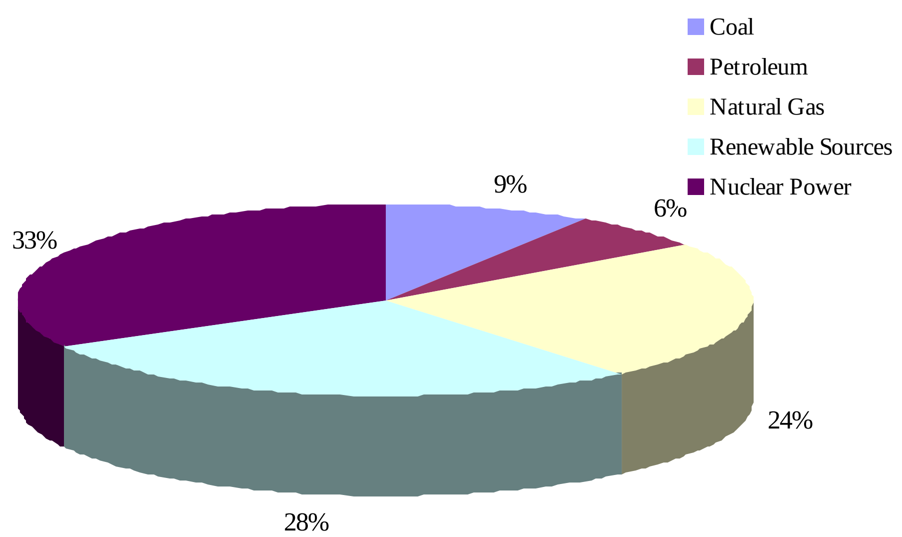

Fig 4:The proportion of energy when $\omega_1 : \omega_2 = 0.8 : 0.2$

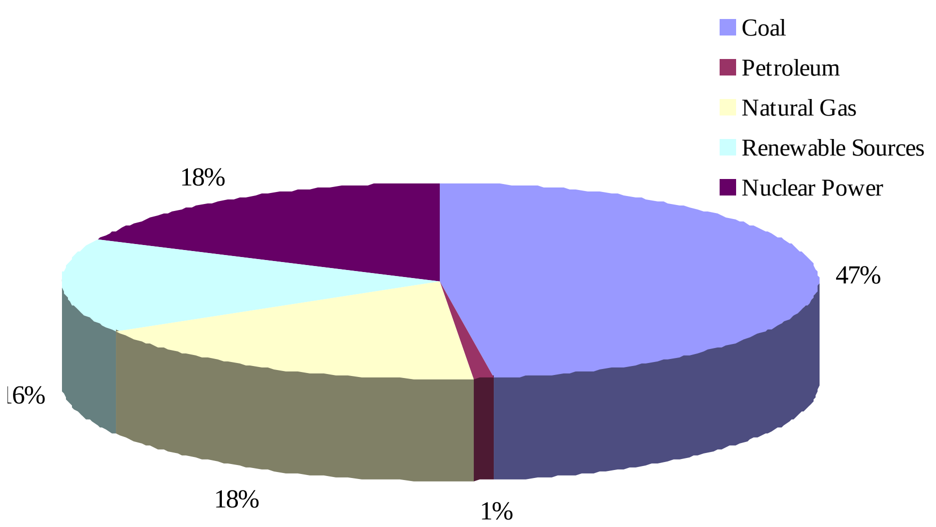

Fig 5:The proportion of energy when $\omega_1 : \omega_2 = 0.2 : 0.8$

2.4.5 Analysis of the Result

- **Efficiency:** GA is an effective solution algorithm for multiobjective optimization ,it can obtain global optimal solution and has good adaptability.
- **Sensitivity :** The result is quite sensitive to the change of the weights .Different decision-makers can make strategy consistent with their own interests.
- **Comparison:**With the increase in the proportion of electric vehicles ，more renewable sources is consumed.The pie charts above show electric vehicle is more environmentally than fossil fuel-burning vehicles.
- **Trend:** In the future,growth of these alternate sources will be larger.

III. Strength and Weakness

3.1Strength

Comprehensive evaluation model based on dates of various types of gases,so the result is very objective and impartial.

The analytic hierarchy process model has strong scientific,and provides Comparison Matrix for different decision-makers to make the appropriate decision strategy.So it has great fitness.

Genetic algorithm can effectively solve the nonlinear optimization problem, get a good approximate optimal solution.Moreover , multi-objective optimization model is fit for optimization of energy structure,for example water resources.

3.2Weakness

As the uncertainty of forecasts, some of the objectives and constraints may be overestimated or underestimated,the model is still an approximate on a certain scale.multi-objective optimization model complicated to solve.

IV.Conclusions and future work

Comprehensive evaluation model show that electric vehicles have advantages over fossil fuel-burning vehicles on the environment, health.However， fossil fuel-burning vehicles perform better than electric vehicles in terms of cost and social facilities.Therefore, considering the long term ,the Government should support the production of electric cars, but due to the high cost of electric vehicles .Governments and vehicle manufacturers can take the following policies in the promotion of electric vehicles:

1）Governments serve financial assistance for electric vehicles and their components research and development activities .

2）Offer some of the benefits to the electric car manufacturers and buyers.

3）The Government should increase the electric vehicle charging stations and other infrastructure construction.

4）Accelerate the research and development, reduce costs

According to the result,the widespread use of electric car can greatly reduce oil comsumption ,but will increase the coal, nature gas comsumption. Therefore, the Government can develop wind, solar and other new energy power generation to solve the problem of fossil fuels shortages.

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